

**ATOMET 4601** is a highly compressible, water-atomized alloy steel powder containing 1.8% nickel and 0.55% molybdenum. It is designed for high performance, high strength powder metallurgy and powder forging applications.

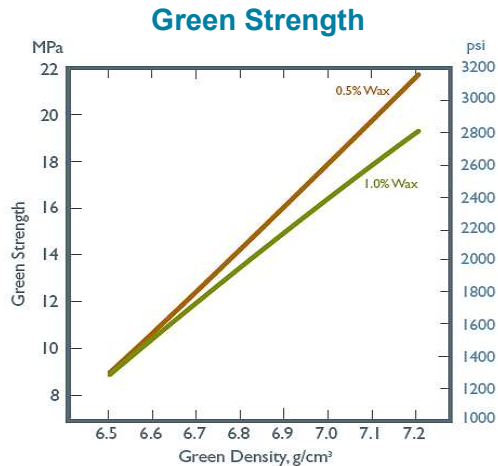
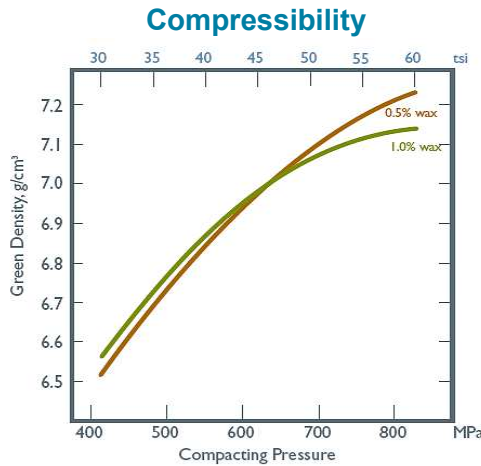
- **High Hardenability** - the precise levels of manganese, molybdenum and nickel enhance heat-treated properties for improved hardness and strength. **ATOMET 4601** can be sinter-hardened when admixed with copper.
- **High compressibility** - outstanding compressibility extends the benefits of low alloy compositions to high-density applications over 6.8 g/cm<sup>3</sup>. Higher strength, higher density PM parts with reduced tool stress become possible.
- **Dimensional change** - **ATOMET 4601** can be used with existing tooling designed for conventional AISI 4600 prealloyed powders. Retooling is not required.

## PHYSICAL AND CHEMICAL PROPERTIES

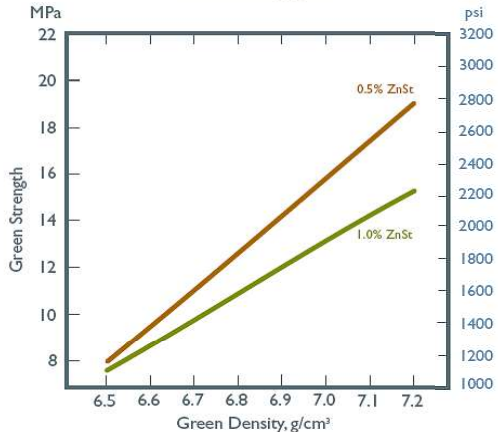
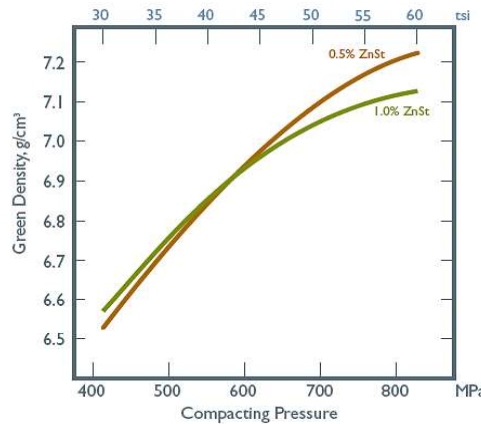
Chemistry, wt%						Particle Size Analysis, wt%				A.D.	Flow	Density*	
C	O	S	Mn	Mo	Ni	U.S. mesh	+60	+100	+325	-325	g/cm <sup>3</sup>	s/50g	g/cm <sup>3</sup>
0.004	0.10	0.01	0.20	0.55	1.80	µm	+250	+150	+45	-45	2.92	26	6.95
							Trace	10	65	25			*@43.5 tsi @600 MPa

## COMPACTING PROPERTIES

**ATOMET 4601  
+ Wax**



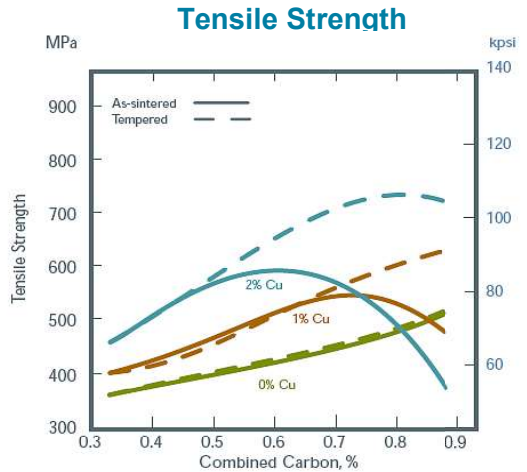
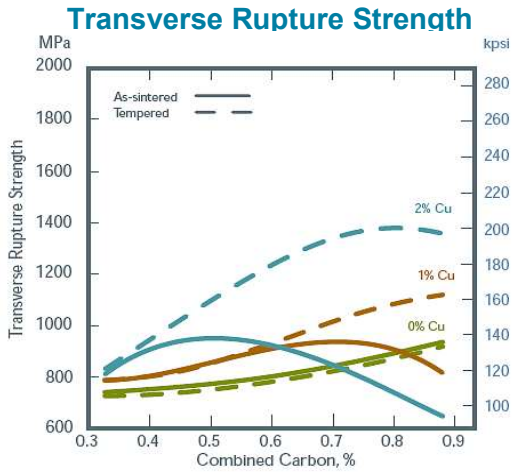
**ATOMET 4601  
+ ZnSt**



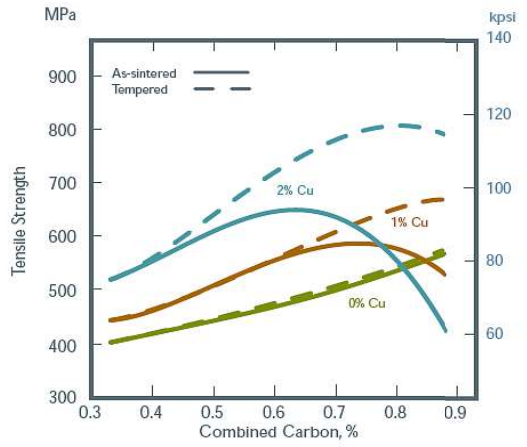
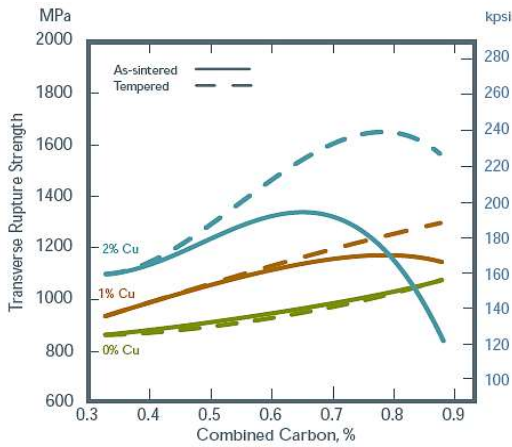
**SINTERED PROPERTIES - Slow Cooled**

Composition: **ATOMET 4601** + copper + graphite + 0.75% ZnSt.  
 Sintered in a 90% nitrogen-based atmosphere at 1120°C (2050°F) for 25 minutes.  
 Cooling rate of 0.4°C/s from 650°C (1200°F) to 400°C (750°F).

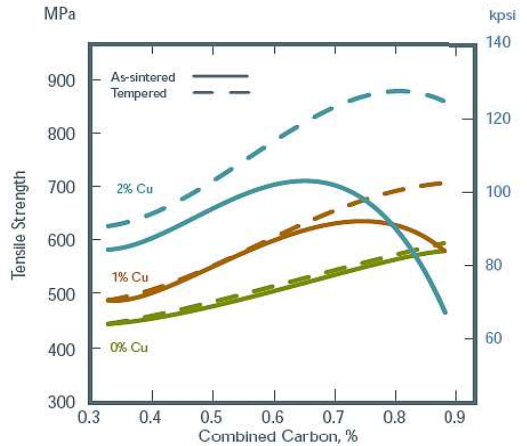
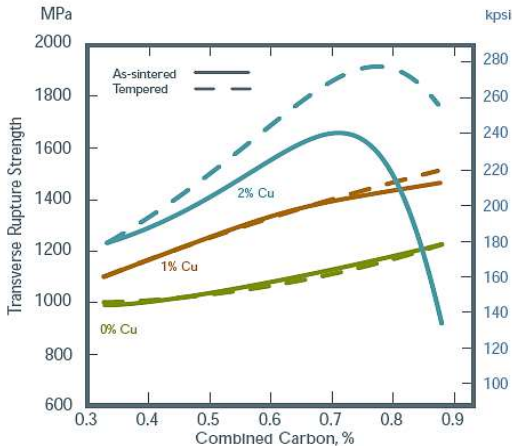
Sintered Density  
 6.7 g/cm<sup>3</sup>



Sintered Density  
 6.9 g/cm<sup>3</sup>



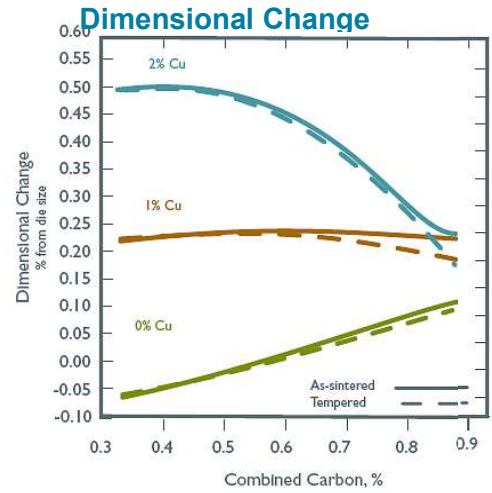
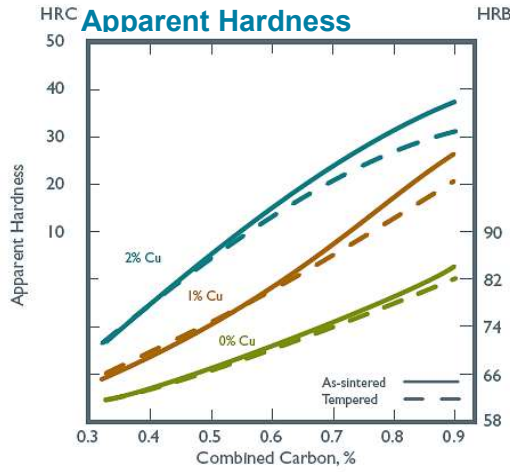
Sintered Density  
 7.1 g/cm<sup>3</sup>



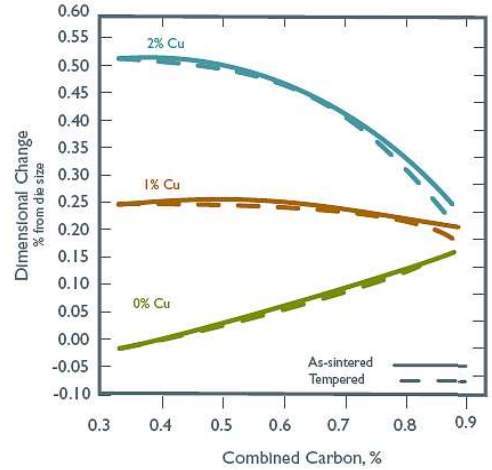
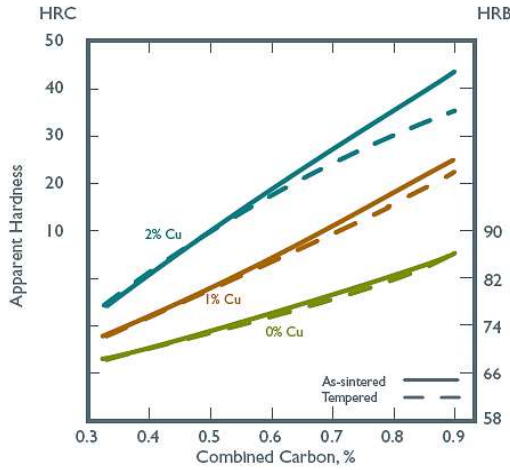
SINTERED PROPERTIES (continued) - Slow Cooled

Composition: **ATOMET 4601** + copper + graphite + 0.75% ZnSt  
 Sintered in a 90% nitrogen-based atmosphere at 1120°C (2050°F) for 25 minutes.  
 Cooling rate of 0.4°C/s from 650°C (1200°F) to 400°C (750°F).

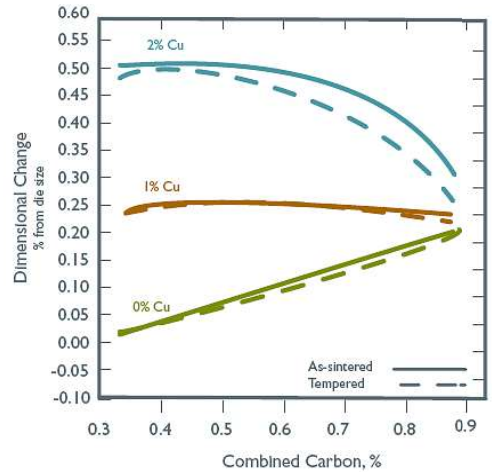
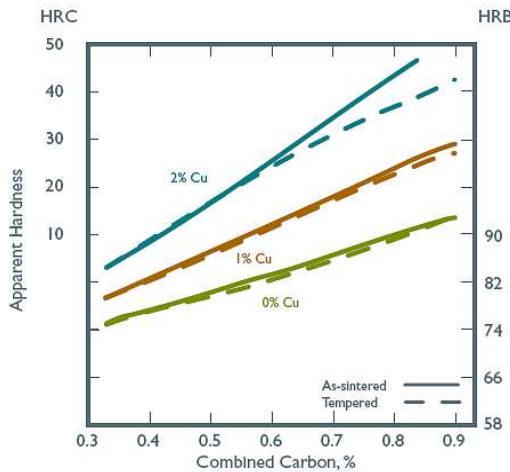
Sintered Density  
 6.7 g/cm<sup>3</sup>



Sintered Density  
 6.9 g/cm<sup>3</sup>



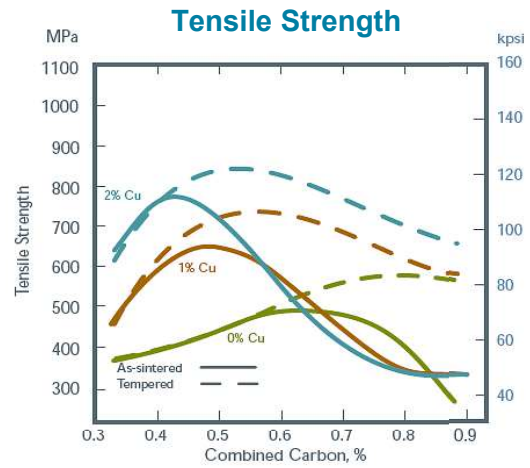
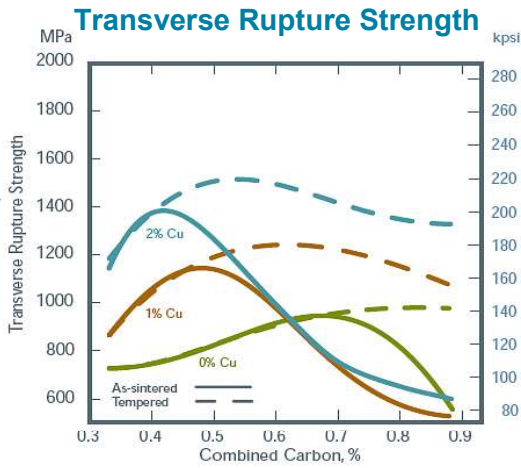
Sintered Density  
 7.1 g/cm<sup>3</sup>



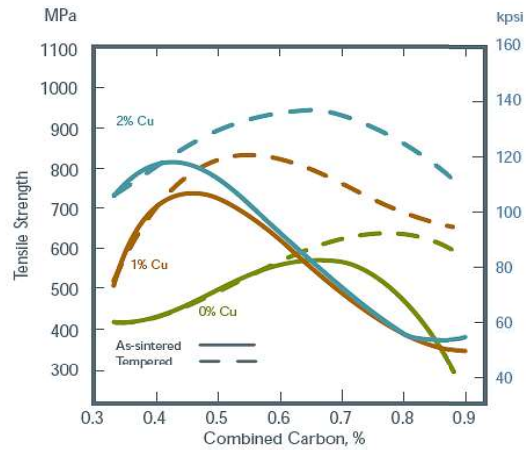
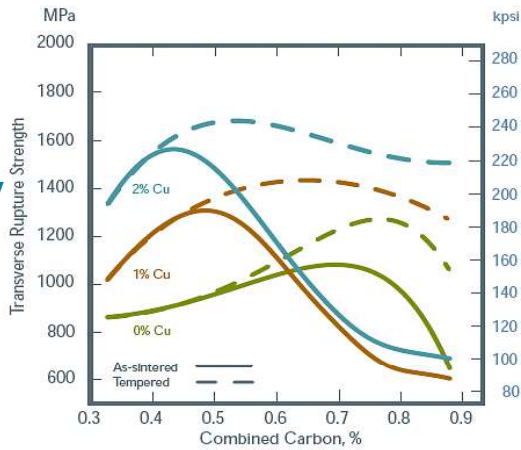
**SINTERED PROPERTIES - Fast Cooled**

Composition: **ATOMET 4601** + copper + graphite + 0.75% ZnSt.  
 Sintered in a 90% nitrogen-based atmosphere at 1120°C (2050°F) for 20 minutes.  
 Cooling rate of 1.5°C/s from 650°C (1200°F) to 400°C (750°F).

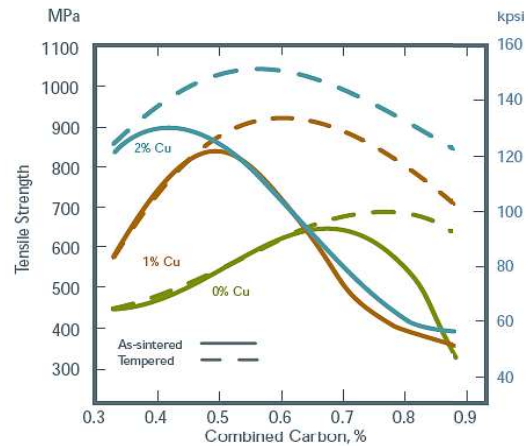
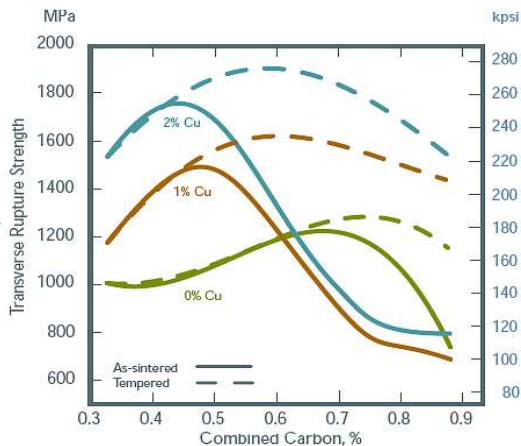
Sintered Density  
 6.7 g/cm<sup>3</sup>



Sintered Density  
 6.9 g/cm<sup>3</sup>



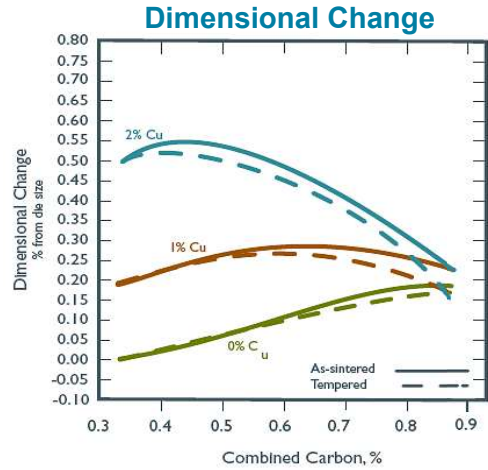
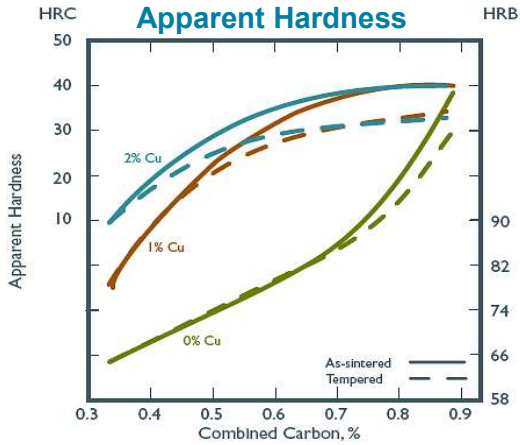
Sintered Density  
 7.1 g/cm<sup>3</sup>



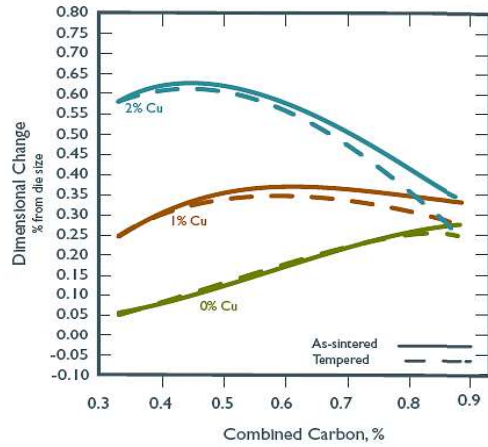
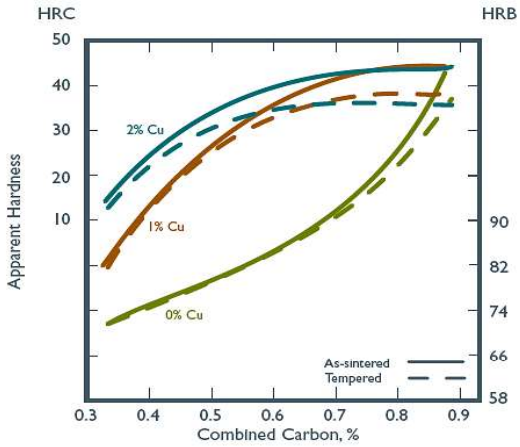
SINTERED PROPERTIES (continued) - Fast Cooled

Composition: **ATOMET 4601** + copper + graphite + 0.75% ZnSt.  
 Sintered in a 90% nitrogen-based atmosphere at 1120°C (2050°F) for 20 minutes.  
 Cooling rate of 1.5°C/s from 650°C (1200°F) to 400°C (750°F).

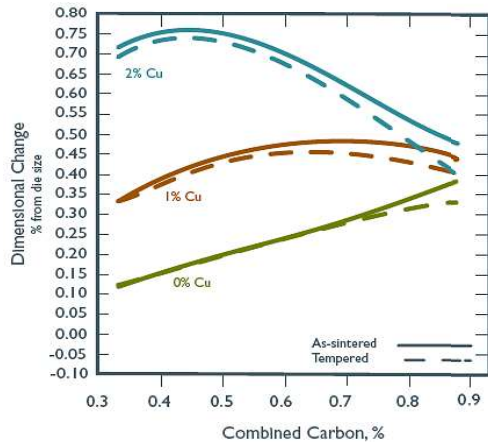
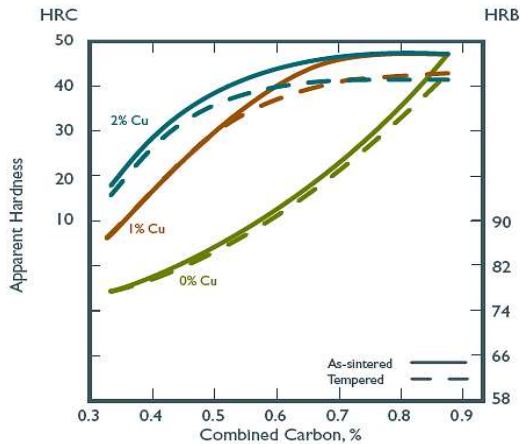
Sintered Density  
 6.7 g/cm<sup>3</sup>



Sintered Density  
 6.9 g/cm<sup>3</sup>



Sintered Density  
 7.1 g/cm<sup>3</sup>



## AS-SINTERED PROPERTIES - Slow cooled\*

Sintered Density	Added Copper	Combined Carbon	Transverse Rupture Strength		Apparent Hardness	Dimensional Change	Tensile Strength		Yield Strength		Elongation
			MPa	kpsi			MPa	kpsi	MPa	kpsi	
6.70	0	0.32	731	106	(61)	-0.07	359	52	290	42	1.6
6.91	0	0.32	855	124	(70)	-0.01	400	58	324	47	1.7
7.13	0	0.32	1000	145	(77)	0.04	441	64	352	51	1.9
6.70	0	0.49	793	115	(67)	-0.01	400	58	310	45	1.6
6.90	0	0.49	917	133	(74)	0.03	441	64	345	50	1.7
7.13	0	0.49	1055	153	(81)	0.10	483	70	386	56	1.7
6.68	0	0.67	827	120	(74)	0.04	393	57	345	50	<1
6.89	0	0.67	945	137	(79)	0.09	483	70	386	56	1.1
7.12	0	0.67	1117	162	(86)	0.16	531	77	421	61	1.2
6.68	0	0.86	903	131	(81)	0.10	483	70	407	59	<1
6.89	0	0.86	1055	153	(87)	0.17	558	81	448	65	1.0
7.12	0	0.86	1193	173	(91)	0.23	579	84	496	72	1.0
6.65	1	0.33	752	109	(64)	0.21	379	55	303	44	1.4
6.86	1	0.33	889	129	(71)	0.25	434	63	331	48	1.5
7.08	1	0.33	1096	159	(79)	0.25	476	69	372	54	1.5
6.66	1	0.49	800	116	(74)	0.23	448	65	345	50	1.0
6.87	1	0.49	1007	146	(80)	0.24	490	71	400	58	1.0
7.08	1	0.49	1248	181	(86)	0.26	538	78	421	61	1.1
6.66	1	0.67	889	129	(87)	0.23	517	75	434	63	<1
6.87	1	0.67	1110	161	(90)	0.24	572	83	483	70	<1
7.08	1	0.67	1344	195	16	0.27	621	90	517	75	<1
6.66	1	0.87	779	113	23	0.21	455	66	434	63	<1
6.87	1	0.87	1089	158	24	0.21	510	74	490	71	<1
7.10	1	0.87	1407	204	25	0.24	565	82	510	74	<1
6.60	2	0.31	827	120	(68)	0.46	414	60	317	46	1.3
6.79	2	0.31	965	140	(75)	0.49	490	71	365	53	1.6
7.02	2	0.31	1193	173	(82)	0.52	545	79	407	59	1.9
6.60	2	0.49	979	142	(83)	0.49	524	76	407	59	<1
6.81	2	0.49	1117	162	(86)	0.49	586	85	455	66	<1
7.02	2	0.49	1344	195	13	0.51	634	92	476	69	<1
6.62	2	0.67	951	138	25	0.39	538	78	476	69	<1
6.83	2	0.67	1213	176	28	0.40	600	87	524	76	<1
7.04	2	0.67	1586	230	30	0.46	676	98	572	83	<1
6.66	2	0.87	710	103	36	0.21	352	51	-	-	<1
6.86	2	0.87	800	116	39	0.24	421	61	-	-	<1
7.08	2	0.87	945	137	45	0.31	441	64	-	-	<1

\* All mixes contain 0.75% ZnSt. Sintered in a 90% nitrogen-based atmosphere at 1120°C (2050°F) for 25 minutes. Cooling rate of 0.40C/s from 650°C (1200°F) to 400°C (750°F).

## TEMPERED PROPERTIES\*\* - Slow cooled \*

Sintered Density	Added Copper	Combined Carbon	Transverse Rupture Strength		Apparent Hardness	Dimensional Change	Tensile Strength		Yield Strength		Elongation
			MPa	kpsi			MPa	kpsi	MPa	kpsi	
6.71	0	0.31	731	106	(62)	-0.06	359	52	296	43	1.5
6.91	0	0.31	869	126	(70)	-0.01	393	57	324	47	1.7
7.14	0	0.31	1020	148	(77)	0.04	455	66	359	52	2.0
6.70	0	0.49	758	110	(67)	-0.01	393	57	310	45	1.6
6.91	0	0.49	903	131	(74)	0.04	448	65	352	51	1.7
7.13	0	0.49	1062	154	(81)	0.11	483	70	386	56	1.7
6.69	0	0.69	814	118	(73)	0.02	434	63	359	52	1.0
6.89	0	0.69	931	135	(80)	0.09	496	72	393	57	1.3
7.12	0	0.69	1103	160	(86)	0.15	538	78	434	63	1.3
6.66	0	0.88	896	130	(81)	0.09	490	71	407	59	<1
6.89	0	0.88	1076	156	(87)	0.16	565	82	455	66	1.0
7.12	0	0.88	1241	180	(92)	0.22	586	85	490	71	1.0
6.65	1	0.35	745	108	(64)	0.22	379	55	303	44	1.3
6.86	1	0.35	903	131	(72)	0.25	427	62	338	49	1.5
7.08	1	0.35	1103	160	(79)	0.25	476	69	386	56	1.5
6.65	1	0.50	820	119	(74)	0.23	441	64	352	51	<1
6.86	1	0.50	979	142	(80)	0.25	496	72	393	57	1.0
7.08	1	0.50	1262	183	(86)	0.25	545	79	441	64	1.0
6.66	1	0.71	938	136	(86)	0.23	531	77	448	65	<1
6.87	1	0.71	1165	169	(90)	0.24	586	85	496	72	<1
7.09	1	0.71	1372	199	15	0.28	634	92	531	77	<1
6.67	1	0.92	1069	155	19	0.18	614	89	503	73	0.7
6.97	1	0.92	1351	196	20	0.19	669	97	565	82	0.6
7.11	1	0.92	1524	221	24	0.23	696	101	600	87	0.5
6.60	2	0.33	807	117	(70)	0.49	421	61	310	45	1.2
6.79	2	0.33	965	140	(75)	0.52	483	70	372	54	1.5
7.01	2	0.33	1131	164	(82)	0.51	545	79	407	59	2.0
6.60	2	0.51	965	140	(82)	0.50	524	76	427	62	<1
6.80	2	0.51	1165	169	(86)	0.49	600	87	476	69	<1
7.02	2	0.51	1407	204	(92)	0.50	655	95	517	75	<1
6.62	2	0.71	1241	180	21	0.38	669	97	496	72	<1
6.83	2	0.71	1510	219	24	0.41	738	107	572	83	<1
7.04	2	0.71	1765	256	27	0.42	827	120	676	98	<1
6.68	2	0.92	1331	193	29	0.16	689	100	545	79	<1
6.87	2	0.92	1531	222	33	0.20	779	113	614	89	<1
7.09	2	0.92	1731	251	38	0.26	841	122	696	101	<1

\* All mixes contain 0.75% ZnSt. Sintered in a 90% nitrogen-based atmosphere at 1120°C (2050°F) for 25 minutes. Cooling rate of 0.4°C/s from 650°C (1200°F) to 400°C (750°F).

\*\* Tempered 60 minutes at 200°C (390°F).

## AS-SINTERED PROPERTIES - Fast cooled \*

Sintered Density	Added Copper	Combined Carbon	Transverse Rupture Strength		Apparent Hardness	Dimensional Change	Tensile Strength		Yield Strength		Elongation
			MPa	kpsi			MPa	kpsi	MPa	kpsi	
6.69	0	0.33	703	102	(64)	0.01	372	54	290	42	1.3
6.90	0	0.33	862	125	(72)	0.06	386	56	324	47	1.4
7.12	0	0.33	1007	146	(79)	0.13	448	65	365	53	1.4
6.68	0	0.51	820	119	(73)	0.06	441	64	338	49	1.1
6.89	0	0.51	965	140	(79)	0.12	490	71	372	54	1.2
7.11	0	0.51	1082	157	(86)	0.21	538	78	414	60	1.2
6.66	0	0.70	903	131	(84)	0.13	469	68	414	60	<1
6.87	0	0.70	1096	159	14	0.21	545	79	448	65	<1
7.10	0	0.70	1207	175	19	0.28	648	94	565	82	<1
6.66	0	0.88	524	76	39	0.18	228	33	-	-	<1
6.86	0	0.88	676	98	41	0.26	331	48	-	-	<1
7.09	0	0.88	710	103	48	0.37	303	44	-	-	<1
6.65	1	0.33	807	117	(75)	0.18	441	64	331	48	<1
6.84	1	0.33	951	138	(83)	0.24	503	73	386	56	1.0
7.07	1	0.33	1151	167	(86)	0.32	558	81	407	59	1.1
6.64	1	0.52	1117	162	19	0.25	621	90	531	77	<1
6.84	1	0.52	1276	185	26	0.33	738	107	600	87	<1
7.05	1	0.52	1441	209	28	0.42	814	118	593	86	<1
6.64	1	0.71	710	103	38	0.25	414	60	-	-	<1
6.84	1	0.71	834	121	40	0.34	483	70	-	-	<1
7.05	1	0.71	896	130	46	0.45	517	75	-	-	<1
6.65	1	0.89	503	73	40	0.20	290	42	-	-	<1
6.84	1	0.89	600	87	45	0.30	345	50	-	-	<1
7.07	1	0.89	648	94	48	0.42	331	48	-	-	<1
6.57	2	0.33	1048	152	(89)	0.50	586	85	441	64	<1
6.77	2	0.33	1186	172	(91)	0.52	662	96	490	71	<1
6.99	2	0.33	1441	209	17	0.63	786	114	524	76	1.1
6.58	2	0.53	1158	168	26	0.50	676	98	593	86	<1
6.78	2	0.53	1338	194	31	0.57	772	112	669	97	<1
6.99	2	0.53	1579	229	36	0.68	807	117	689	100	<1
6.61	2	0.72	731	106	36	0.37	352	51	-	-	<1
6.81	2	0.72	814	118	40	0.47	421	61	-	-	<1
7.02	2	0.72	972	141	45	0.58	510	74	-	-	<1
6.65	2	0.89	579	84	40	0.18	317	46	-	-	<1
6.84	2	0.89	662	96	43	0.30	345	50	-	-	<1
7.05	2	0.89	752	109	48	0.44	379	55	-	-	<1

\* All mixes contain 0.75% ZnSt. Sintered in a 90% nitrogen-based atmosphere at 1120°C (2050°F) for 25 minutes. Cooling rate of 1.5°C/s from 650°C (1200°F) to 400°C (750°F).



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**TEMPERED PROPERTIES\*\* - Fast cool \***


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Sintered Density	Added Copper	Combined Carbon	Transverse Rupture Strength		Apparent Hardness	Dimensional Change	Tensile Strength		Yield Strength		Elongation
			MPa	kpsi			MPa	kpsi	MPa	kpsi	
6.70	0	0.33	924	134	(64)	0.00	372	54	296	43	1.3
6.90	0	0.33	1131	164	(71)	0.05	414	60	317	46	1.4
7.12	0	0.33	1303	189	(78)	0.13	462	67	365	53	1.4
6.68	0	0.51	1241	180	(73)	0.06	434	63	338	49	1.1
6.89	0	0.51	1407	204	(79)	0.12	496	72	393	57	1.1
7.11	0	0.51	1475	214	(86)	0.20	538	78	421	61	1.2
6.67	0	0.70	1096	159	(81)	0.12	572	83	510	74	<1
6.87	0	0.70	1276	185	13	0.21	565	82	462	67	<1
7.10	0	0.70	1379	200	16	0.28	683	99	600	87	<1
6.67	0	0.88	1117	162	28	0.16	531	77	-	-	<1
6.87	0	0.88	1076	156	38	0.24	627	91	-	-	<1
7.10	0	0.88	1220	177	43	0.32	614	89	-	-	<1
6.64	1	0.33	1207	175	(75)	0.18	448	65	365	53	<1
6.84	1	0.33	1510	219	(80)	0.24	503	73	393	57	1
7.06	1	0.33	1689	245	(87)	0.31	552	80	434	63	1.1
6.64	1	0.52	1317	191	17	0.24	689	100	614	89	<1
6.84	1	0.52	1538	223	25	0.32	793	115	689	100	<1
7.05	1	0.52	1834	266	28	0.40	855	124	724	105	<1
6.64	1	0.71	1338	194	30	0.22	662	96	676	98	<1
6.84	1	0.71	1538	223	33	0.31	779	113	717	104	<1
7.05	1	0.71	1751	254	39	0.42	869	126	855	124	<1
6.65	1	0.89	1076	156	33	0.14	572	83	558	81	<1
6.84	1	0.89	1200	174	37	0.25	648	94	600	87	<1
7.07	1	0.89	1351	196	42	0.38	689	100	648	94	<1
6.57	2	0.33	1207	175	(87)	0.51	524	76	476	69	<1
6.76	2	0.33	1448	210	(89)	0.55	648	94	531	77	<1
6.99	2	0.33	1779	258	14	0.63	779	113	634	92	<1
6.58	2	0.53	1351	196	21	0.48	752	109	641	93	<1
6.78	2	0.53	1572	228	27	0.56	848	123	752	109	<1
6.99	2	0.53	1903	276	33	0.66	972	141	855	124	<1
6.61	2	0.72	1510	219	27	0.33	696	101	641	93	<1
6.81	2	0.72	1620	235	34	0.43	814	118	724	105	<1
7.02	2	0.72	1931	280	38	0.55	938	136	807	117	<1
6.67	2	0.89	1262	183	32	0.13	662	96	545	79	<1
6.85	2	0.89	1462	212	37	0.24	717	104	545	79	<1
7.07	2	0.89	1551	225	41	0.37	841	122	648	94	<1

\* All mixes contain 0.75% ZnSt. Sintered in a 90% nitrogen-based atmosphere at 1120°C (2050°F) for 25 minutes. Cooling rate of 1.5°C/s from 650°C (1200°F) to 400°C (750°F).

\*\* Tempered 60 minutes at 200°C (390°F).

## HEAT-TREATED PROPERTIES

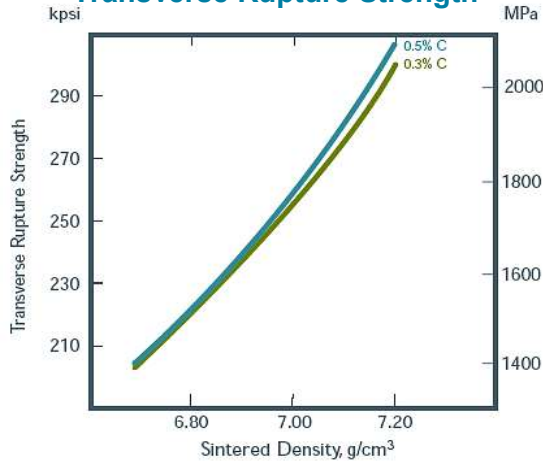
Composition: **ATOMET 4601** + graphite + 0.75% ZnSt.

Sintered in a rich endothermic atmosphere at 1120°C (2050°F) for 30 minutes.

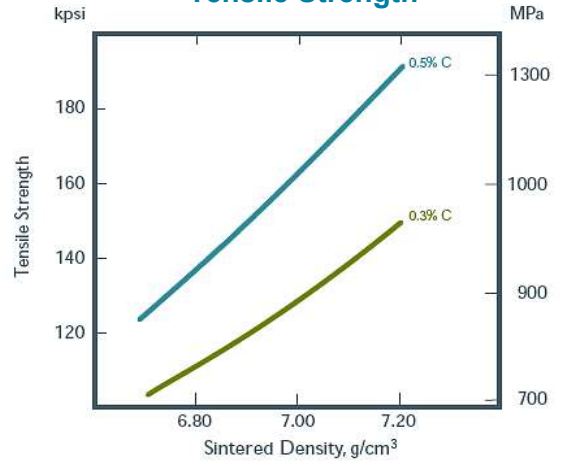
Heat-treated 15 minutes at 845°C (1550°F), atmosphere with 0.8% carbon potential.

Oil quenched at 50°C (125°F), tempered 60 minutes at 185°C (365°F).

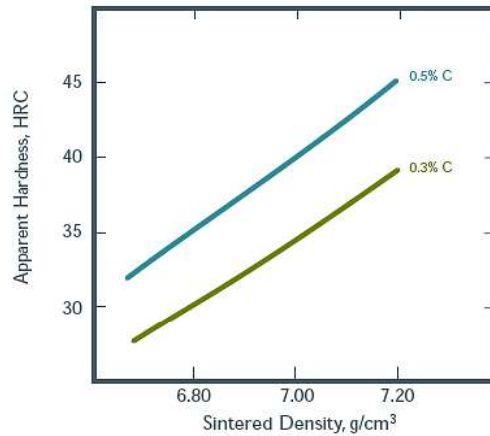
**Transverse Rupture Strength**



**Tensile Strength**



**Apparent Hardness**



Material Designation Code	Green Density	Added Graphite	Combined Carbon	Transverse Rupture Strength		Apparent Hardness	Combined Carbon	Tensile Strength	
				MPa	kpsi			MPa	kpsi
MPIF std 35	g/cm³	%	%			HRC	%		
FL-4603-HT	6.80	0.3	0.29-0.35	1520	220	29	0.29-0.35	760	110
	7.00	0.3	0.29-0.35	1770	256	35	0.29-0.35	900	131
	7.10	0.3	0.29-0.35	1920	278	37	0.29-0.35	990	144
FL-4605-HT	6.80	0.5	0.46-0.52	1500	218	33	0.46-0.52	880	127
	7.00	0.5	0.46-0.52	1790	260	39	0.46-0.52	1030	150
	7.10	0.5	0.46-0.52	1950	283	42	0.46-0.52	1150	167

All mixes contain 0.75% ZnSt. Sintered in a rich endothermic atmosphere at 1120°C (2050°F) for 30 minutes.

Heat treatment: 15 minutes at 845°C(1550°F) in atmosphere with 0,8% carbon potential. Oil quenched at 50°C (125°F).

Tempered 60 minutes at 185°C (365°F).

**METALLOGRAPHIC ANALYSIS**

ATOMET 4601, with the lowest level of non-metallic inclusions, is an ideal choice for fully dense applications which demand exceptional mechanical and dynamic properties.

**I. Non-Metallic Inclusions**

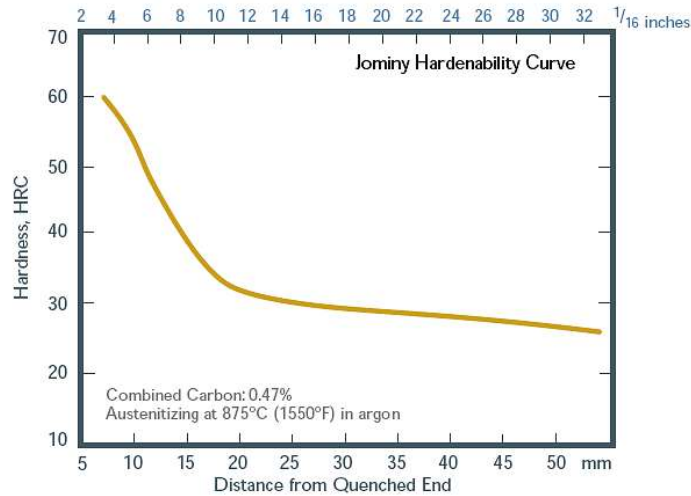
A) Total surface area of inclusions: **0.004**

B) Inclusions count:

Length µm	Number/ 100 mm <sup>2</sup>
30/50	2.0
50/100	0.7
100/150	0.1
>150	0.0

**II. Unalloyed Iron: < 0.2%**

**Hardenability at Full Density**



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